Sensing Sea Surface Winds With Passive Microwave Techniques

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The turbulent interactions of the two fluid bodies representing the Earth's atmosphere and its oceans are key parameters affecting regional weather, ocean circulation, and global climate. One agent of this interplay is the atmospheric wind blowing across an ocean surface which transports energy, moisture, and gases between the two fluids. Thus, a true understanding of the air-sea interface relies upon being able to quantify the strength and direction of sea surface winds blowing over the entire globe. Real-time mapping of near-surface ocean winds also provides crucial information for the commercial and military seafaring vessels navigating the world's open seas.

Historically, ocean buoy and ship measurements have been the primary source of marine wind speed and direction. These discrete point sources, however, do not provide the uniform global coverage required for near-surface ocean wind mapping. In recent years, active and passive microwave radiation detection methods have shown great promise in providing this global coverage from spaceborne platforms. Both techniques rely on detecting wind-generated changes to ocean wave structures. Active microwave sensors called scatterometers are currently flying on satellites which can remotely sense both ocean wind speed and direction while passive microwave instruments called radiometers are measuring only wind speed from present day satellites.

The next evolutionary step to sea surface wind measurement from space is the development of passive microwave radiometers which could retrieve both wind speed and direction. As technology improves, this goal appears to be more attainable than had been previously envisioned. Shrinking governmental budgets have, in turn, made this goal a necessity for future satellite programs because radiometers can be built with significantly less expense than can scatterometers.

To help determine the feasibility of this goal, a prototype satellite instrument is currently being developed by Marshall to passively sense both sea surface wind speed and direction. The instrument is called the conically-scanning two look airborne radiometer (C-STAR). It has been designed to test spaceborne measurement techniques from a NASA high-altitude aircraft flying at a nominal altitude of 20 km. C-STAR will scan beneath the aircraft in a circular pattern subtended by an angle of 53 degrees from the aircraft nadir. Microwave radiation naturally emitted by the Earth and its atmosphere at a 37.1 GHz frequency will be detected by four receivers aligned to intercept energy at four different polarizations (i.e., horizontal, vertical, +45 degrees from vertical, and –45 degrees from vertical). By comparing data imagery collected at different segments of the circular scan as well as at different polarizations, the anisotropic nature of the radiometric signature of the sea surface wind should be revealed.

The first test flights of the C-STAR will take place in early 1997 off the western coast of the United States. The aircraft missions will be flown over ocean buoy sites providing ground truth wind vector (i.e., speed and direction) measurements. These ground truth data will validate and quantify the magnitude of the sea surface wind signals mapped by the C-STAR imagery. This investigation will highlight the capabilities and limitations of near surface ocean wind vector retrievals which could be derived from satellite passive microwave imagery. This type of knowledge is important to the planners and designers of future spaceborne instrumentation who have the dual challenge of seeking to increase our understanding of the Earth's weather and climate while being mindful of cost-efficient measures.

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Remote Sensing of Winds Using Airborne Doppler Lidar

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The wind occupies a central role in weather and climate, and its effects can be observed over a wide range of spatial and temporal scales. The wind transports heat, moisture, momentum, radiatively-active trace gases, biogeochemicals, and microscopic particles (aerosols). This redistribution and the interaction with latent heat and radiation produce weather and climate. On a daily basis these interactions can take the form of processes and features that are easily recognizable, such as convection and clouds, precipitation, jet streams, extratropical cyclones, and hurricanes.

For nearly 30 years, coherent Doppler lidar (or laser radar) has been used to remotely sense the atmospheric wind. Lidar is an acronym for light detection and ranging. The term "coherent" refers to the use of the phase information in the outgoing and incoming radiation. During lidar operation a pulse of light is emitted from the laser, scattered backward along the line of sight by clouds, dust, or other aerosols, and a Doppler frequency shift imparted by the relative motion of the scatterers. The lidar receiver converts the signals to line-of-sight (LOS) velocity as a function of range. Doppler lidar measures signals primarily from optically clear air, however velocities can be measured within or through thin clouds. Doppler lidar has a demonstrated capability to measure atmospheric dynamical processes and features over locations and scales of motion that are frequently beyond the measurement capabilities of conventional sensors. When placed on an aircraft, the measurement capability of Doppler lidar is enhanced considerably.

Scientific recognition of the relative contribution of small-scale atmospheric processes, and in particular their interaction with large-scale processes, has grown over the past 10 to 15 years. In parallel, technological advances in high-energy lasers have expanded the potential of Doppler lidar remote wind sensing for atmospheric research. The lidar remote sensing groups of MSFC, NOAA Environmental Technology Laboratory (ETL), and Jet Propulsion Laboratory (JPL) developed an airborne scanning Doppler lidar termed the multi-center airborne coherent atmospheric wind sensor (MACAWS). The centerpiece of MACAWS is a high-energy CO_2 gas laser, making this perhaps the most powerful Doppler lidar developed for airborne atmospheric research. MACAWS has the key capability to measure winds remotely over a three-dimensional volume. During operation, pulses of eye-safe laser radiation (or "beams") are directed into the atmosphere through the left side of the aircraft using a pair of internally mounted, counter-rotating germanium prisms. By refracting the lidar beam forward and aft of the aircraft heading in an alternating manner such that the LOS velocity vectors fall within a common plane, two-dimensional wind velocities may be calculated at points of intersection between the forward and aft-pointing beams (fig.154). The contribution to the Doppler shift along the line of sight due to scan angle and aircraft attitude and speed are removed by using measurements from a dedicated inertial navigation system located near the scanner. The net results are measurements of ground-relative wind velocity. The vertical distribution of wind and aerosols over a three-dimensional volume may be obtained by scanning at multiple levels with arbitrary angular separation (fig. 155).

MACAWS was flown on a short series of science demonstration flights for the first time in September 1995 aboard the NASA DC–8 research aircraft. Missions were conducted over the western United States and eastern Pacific Ocean. Highlights included the first airborne simulation of a satellite Doppler wind lidar, and the first Doppler velocity measurement within a

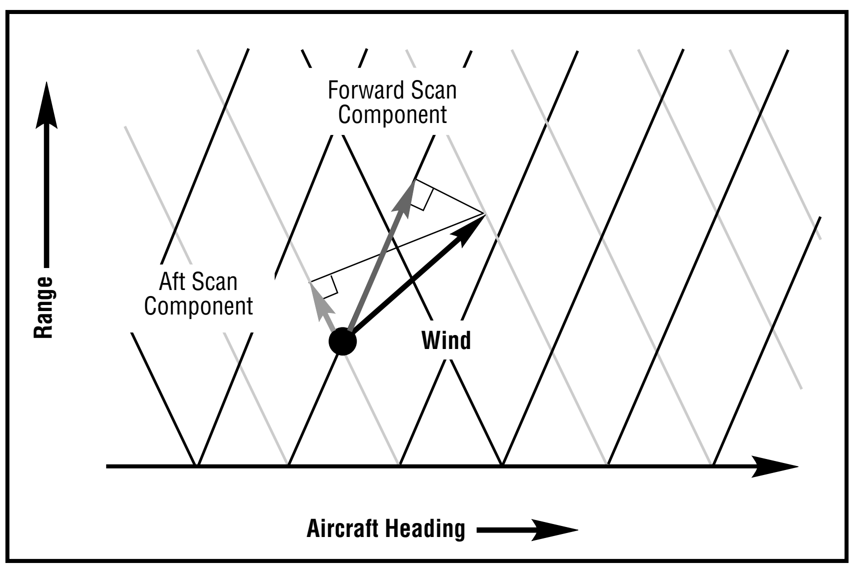

FIGURE 154.—Co-planar scanning method for obtaining two-dimensional wind field measurements. Scanner alternately directs lidar beam forward and aft of aircraft heading; two-dimensional wind vectors are calculated using trigonometry.